JPL WEB TEAM

JET PROPULSION LABORATORY

D. B. Bickler

Web Team

- **Background**
  - **DOE Five-Year Research Plan goals significantly lowered the FSA $/m^2 allowable for modules while raising efficiency requirements**
  - **Silicon sheet costs have not kept pace with reductions in other areas of module fabrication**
  - **Dendritic web viewed as most probable sheet option to meet both $/m^2 and efficiency requirements**
  - **Area throughput rate limiting factor for years in dendritic web economics**

- **May 1983:** DOE issues Five-Year Research Plan
- **June 1984:** JPL reviews ribbon situation and decides to broaden research base in dendritic web
- **September 1984:** Web Team formed to take independent analytical and experimental look at web

  Purchase order placed with Westinghouse for fabrication and delivery of a web growth system
- **November 1984:** JPL internal review of proposed Web Team activities
- **December-January 1984-1985:** Two JPL operators trained at Westinghouse
- **January 1985:** Facilities for growth system tested by exercising test bed furnace
- **February 1985:** Growth system received at JPL
- **April 1985:** Major external review of Web Team activities. First web grown at JPL

Computed Isotherms With and Without the Growing Web

TEMPERATURE - °C ABOVE REFERENCE
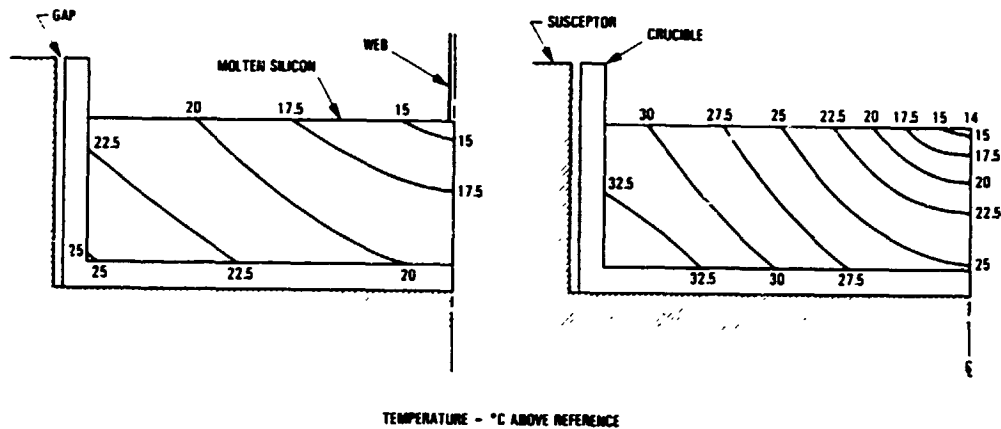
Thermal modeling was done using the "SINDA" program to investigate the effects of varying key parameters
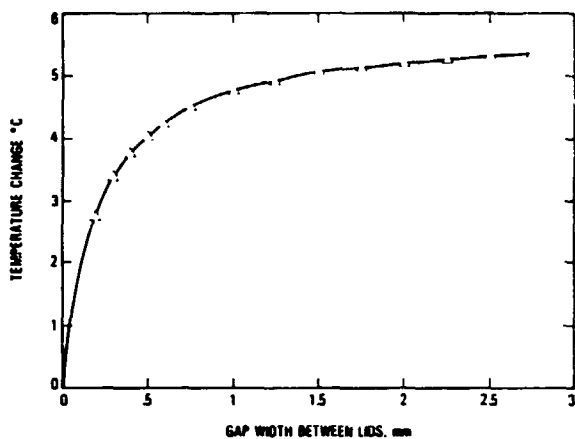
Crucible-to-Susceptor Gap Effect on Surface Temperature
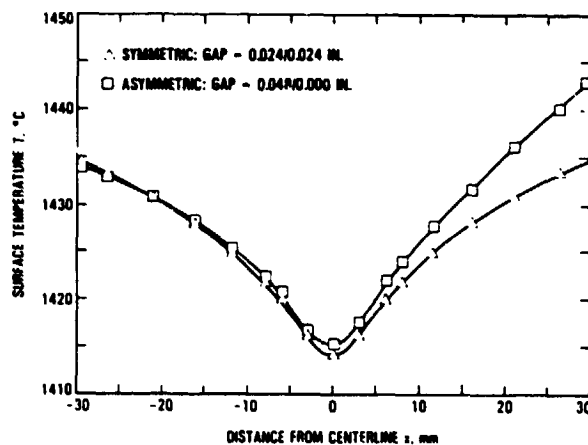
Differential thermal expansion causes a varying gap between the crucible sides and the susceptor. Beyond 0.021 in., gap increase causes insignificant change in heat transfer
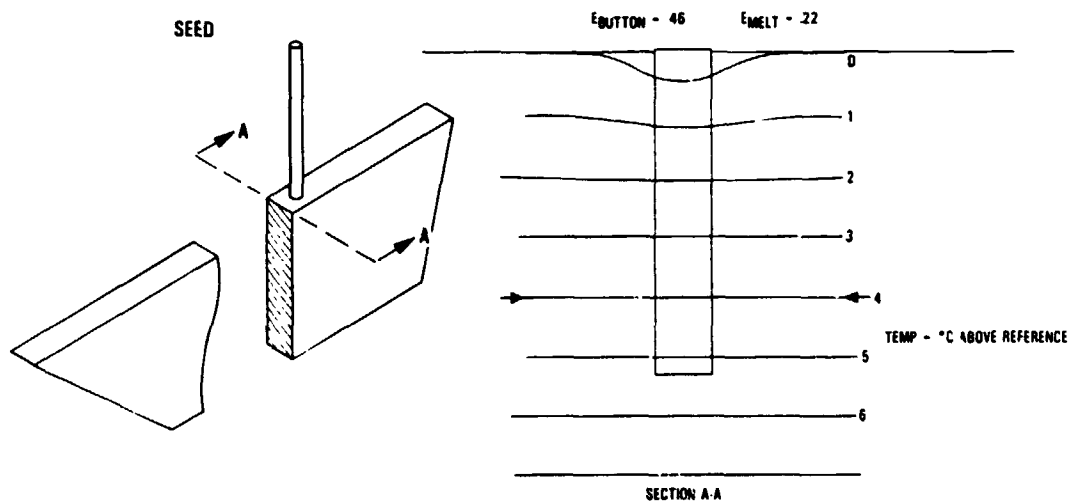
Melt Surface Temperature Change as a Function of Lid Gap

Thermal warping of the molybdenum lids causes a change in heat transfer from the surface of the molten silicon. A 0.5 mm variation in lid gap may cause as much as 4°C change in melt surface temperature
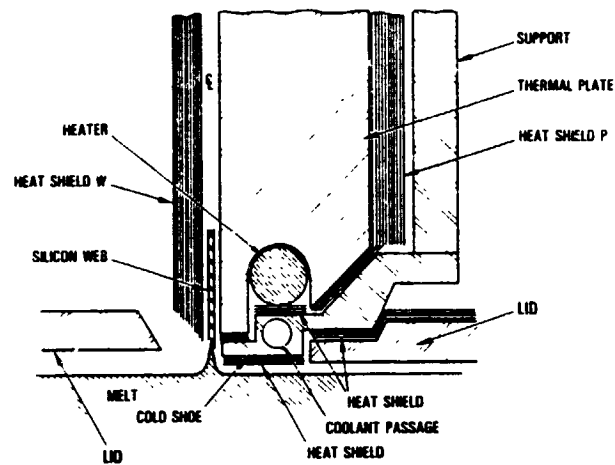
Button Growth

SECTION A-A

The solid to liquid interface cannot be an isotherm (i.e., the freezing pont). A simplified computer run gives a 5°C difference over actual button dimensions.

Cold Shoe

Labels: SUPPORT, THERMAL PLATE, HEAT SHIELD P, HEATER, HEAT SHIELD W, SILICON WEB, LID, MELT, COLD SHOE, LID, HEAT SHIELD, COOLANT PASSAGE, HEAT SHIELD

A "cold shoe" design was analyzed for the feasibility of high heat transfer rates from the growing web. Analysis showed need for severe gradients in shoe as well as sensitivity to small dimensional changes. SiO contamination expected to be a major problem

Benard Cells

Labels: L, VERTICAL DEPTH, COLD, WARM
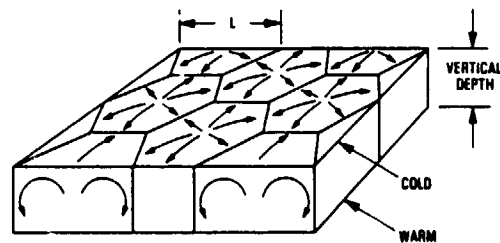
Vertical temperature gradients (from thermal analysis) indicate convection (Benard cells) in molten silicon causes instability at melt depths used
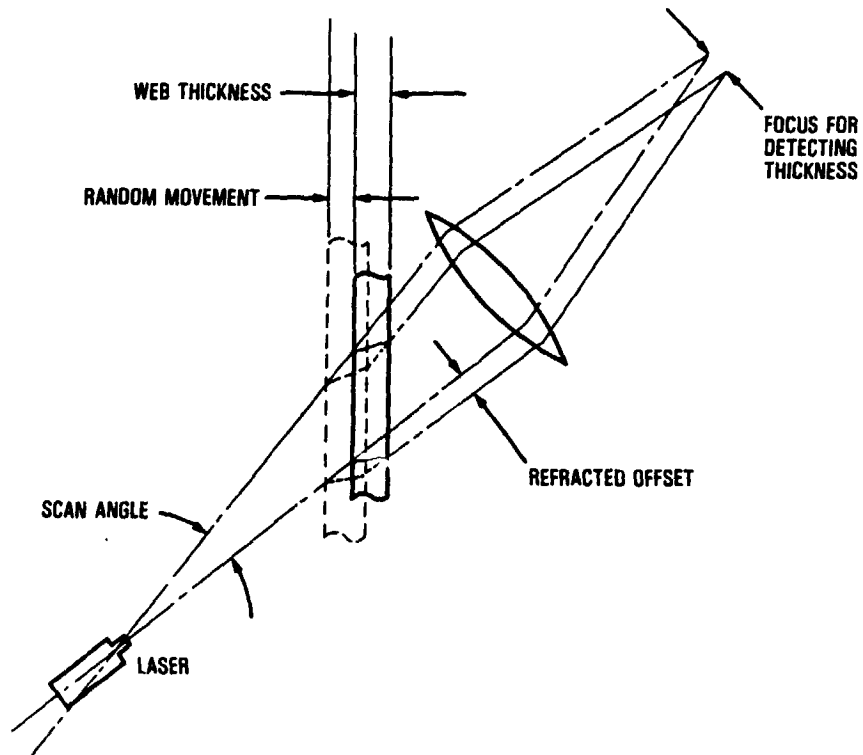
Meniscus Geometry
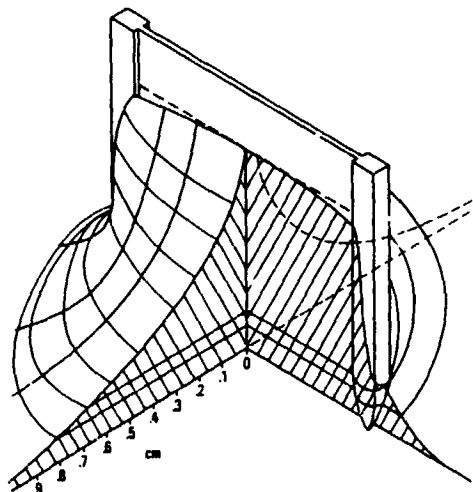
Meniscus shape is dictated by surface tension
of the molten silicon. The meniscus is higher
on the web where a cylindrical curvature
exists. The end meniscus is pulled lower by
the convex horizontal curvature component

Radio Frequency Studies

- Objective
    - Devise means for determining radio frequency coupling
      with furnace elements

- Results
    - Mathematical methods are too complex, require simplifying
      assumptions which dominate results
    - Relatively simple probe, 25 turns 0.250 in. diameter with
      semi-rigid coaxial shaft
    - Without susceptor, inside field about twice that outside of coil
    - Susceptor with shields absorbs over 99.3% of the energy
    - No measurable field in vicinity of web

Scanning Thickness Detector

WEB THICKNESS

RANDOM MOVEMENT

FOCUS FOR
DETECTING
THICKNESS

REFRACTED OFFSET

SCAN ANGLE

LASER

Sensing Head Optical System

Section 7 — MAINTENANCE & FIELD SERVICE

OBJECTIVE
LENS

WINDOW

FOLDING
MIRROR

EYEPIECE

APERTURE

CAL
LAMP

FIELD LENS
AND
RETICLE

DETECTOR
ASSEMBLY
(INSIDE
HEATER
BLOCK)

FIBER OPTIC
CABLE

228